Empirical evidence on foreign exchange market intervention

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Empirical Evidence on Foreign Exchange Market Intervention: Where Do We Stand?

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I. Introduction

In this article a survey will be given of fifteen empirical studies which have been carried out to assess which objectives the central banks of the main industrial countries pursued with their interventions in the foreign exchange market. Furthermore, ten empirical studies addressing the question of whether (sterilized) intervention has been capable of exerting a significant influence on the exchange rate will be reviewed.

Discontent with the outcomes of the current, post Bretton Woods exchange rate system has caused the volume of central bank intervention to increase markedly since the mid-1980s. A prominent feature of the theoretical literature on exchange market intervention is the assumption that central banks try to minimize deviations from a target level for the exchange rate based upon fundamental factors whereas there is no explicit assumption about the behaviour towards short-term volatility of exchange rates [see, e.g. Neumann, 1984; Turnovsky, 1985; Natividad and Stone, 1990]. Apparently, as exporters and importers can hedge against the cost of short-run volatility of spot exchange rates on the forward market for foreign exchange, there seems to be no major problem associated with short-term exchange rate risk.[1] However, a recent study by Bini Smaghi [1991] presents some new evidence on the effect of short-term exchange rate risk on the volume of international trade. For the period 1976–84, the standard

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[1] This is in line with the view that "...the real dangers for practical business and macroeconomics arise not from short-run volatility but from lasting exchange rate disequilibria" [Gärtner, 1987, p. 441].

deviation of weekly rates of change of the intra-EMS effective exchange rate during a quarter appears to have had a significantly negative effect on the volume of exports of the countries considered (Germany, France and Italy) in the same quarter. The results of some tentative estimations carried out by Bordo and Schwartz [1990] indicate that central banks were not successful at limiting short-run volatility of spot exchange rates over the period January 1985–August 1989. No negative correlation is found between monthly intervention by the United States, Germany and Japan and monthly standard deviations of the daily U.S. dollar/deutsche mark and U.S. dollar/yen exchange rates.[2]

In the next section, some general issues concerning foreign exchange market intervention will be discussed. In Section III, a survey of the results of empirical research on the objectives of central bank intervention will be given which is preceded by a concise exposition of some theoretical and technical insights. Analogously, in Section IV, a survey of empirical investigations into the effectiveness will be presented. Section V summarizes the main conclusions.

II. Some General Issues

We define an exchange market intervention as a sale or a purchase of foreign currencies by the monetary authorities with the aim of changing the exchange rate of their own currency vis-à-vis one or more foreign currencies. The distinction that is being made between "active intervention" and "passive intervention" does not seem very helpful to us as far as empirical research is concerned. By definition, passive intervention is distinguished from active intervention in that the transactions are carried out outside instead of inside the exchange market. It is of course at the discretion of a central bank to carry out a sale of foreign exchange inside or outside the market depending on the strength of its own currency.

By far the larger part of exchange market intervention is carried out in the spot market. While "analytically there is no distinction between the effects of forward market and sterilized spot market transactions on the spot exchange rate" [Smith and Madigan, 1988,

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[2] The scepticism of Bordo and Schwarz [1990, p. 23] regarding the efficacy of intervention is best reflected by their assertion that "to find economic grounds for sterilized intervention economists have created a literature of announcement effects that is as nebulous in theory as is the effort to find empirical verification of it".

p. 189], the reason for this seems to be that an intervention operation derives a great deal of its effect from the announcement of the operation itself. Highly visible spot market operations confirm the announcement.

In general, the empirical investigation of objectives and effectiveness of exchange market intervention is hampered by a lack of sufficiently detailed data. It is well known that for example the German and Swiss central banks swap foreign exchange with the commercial banks. Changes in official reserves include these swaps implying they do not accurately reflect intervention. Taylor [1982] puts forward the problem of concealed intervention not showing up in the official international reserve figures. Nationalized industries carrying out interventions probably is a phenomenon of the 1970s.[3]

III. Objectives of Exchange Market Interventions

In the theoretical literature two divisions of objectives can be found. In the Jurgensen report [1983], the objectives are classified according to whether the central bank pursues them on a long-term or a short-term basis, whereas the kind of objective underlying the intervention forms the division criterion for German economists like Lehment [1980] and Sommer [1983]. In our view, the extent of the division of objectives in the Jurgensen report is not in accordance with what the central banks try to do to counteract unwanted exchange rate movements. To formulate medium-term and long-term objectives is one thing. To carry out exchange market interventions aimed at realizing those objectives while one is not even able to control the exchange rate movements in the short run is something totally different.

Although most studies postulate a central bank intervention reaction function rather ad hoc, it can be derived theoretically. For instance, this can be done by combining a policy loss function with a set of equations describing the determination of the exchange rate of currency B in terms of currency A (S_t). The policy loss function reflects the hypothesis that the central bank of country A wishes to limit deviations from a target level for the exchange rate (S_t^T):

$$L_t = (\log S_t - \log S_t^T)^2 = (s_t - s_t^T)^2 , \tag{1}$$

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[3] Taylor [1982] investigates the profitability of foreign exchange market intervention. Therefore, this study does not fit in the framework of our study.

with $s_t = \log S_t$ and $s_t^T = \log S_t^T$. To capture intervention carried out on account of a leaning against the wind policy, the target level for the exchange rate can be thought of as representing past levels of the exchange rate. This follows immediately from the definition of smoothing exchange rate fluctuations: whether or not the exchange rate was considered to be at a desirable level in the previous period(s), deviations from this target level will be countered.

The dramatic increase in the exchange market turnovers has caused proper timing of the interventions and the use of the correct intervention technique to become of growing importance in the exchange rate policy of the central banks. The estimated reaction functions, however, only give an explanation for the volume and direction of intervention transactions. This reduces the explanatory power of the estimated relations. All investigations under review are concerned with spot market interventions only. In the estimated reaction functions the volume of intervention in subsequent periods (I_t) is the dependent variable that has to be explained by the independent variables of which the difference between the actual level of the exchange rate (S_t) and the target level of the exchange rate (S_t^T) is the most important. Obviously, when the estimation is carried out using monthly data, the exchange rate change in one month (independent variable) will be simultaneously determined by the interventions undertaken in the same month. In an attempt to reduce the simultaneity bias, some studies use the two stages least squares (2SLS) or the instrumental variables (IV) estimation technique. In any case, the estimation results have to be interpreted carefully. It should be stressed that the empirical tests of the objectives of intervention policy are rather indirect in the sense that estimates of the reaction functions assume the underlying model to be the true model. Therefore, estimation results may not only be an indication of objectives of intervention policy, but also of the strength of the underlying model.

Henceforth, we will discuss a number of empirical investigations into the objectives of exchange market intervention. Their main characteristics are summarized in Table 1.

Artus [1976] studies the intervention policy of the Bundesbank (DBB) over the period March 1973–July 1975. He finds evidence of a leaning against the wind policy. A rise (fall) by one percentage point in the value of the deutsche mark in terms of the U.S. dollar ($\dot{S}_t$) during one month gave rise to the buying (selling) of DM 0.359 billion worth of foreign exchange over the same one-month period. Furthermore, the German central bank on average bought (sold) DM 463

Table 1 – *Objectives of Foreign Exchange Market Intervention: Some Characteristics of the Studies Reviewed*

Author	Period	Data	Estimation technique	Definition of intervention	Exchange rate	Intervening central bank
Artus [1976]	March '73 – July '75	monthly	2SLS	change in the net foreign assets of the DBB (in bill. of DM) (p. 31)	spot rate of the DM in terms of U.S.$	DBB
Quirk [1977]	March '73 – October '76	monthly	OLS & 2SLS	changes in the Foreign Exchange Fund account (in mill. of $) (p. 650)	spot rate of the yen in terms of U.S.$	BoJ
Branson et al. [1977] Branson et al. [1979]	August '71 – December '76 August '71 – March '78	monthly	2SLS	international reserves of Germany (in U.S.$) minus cumulated SDR allocations (p. 323)	spot rate of the DM in terms of U.S.$, index 1970 = 100	DBB
Dornbusch [1980]	July '73 – December '79	quarterly	OLS	changes in reserves (except for interest earnings) as a fraction of lagged reserves (p. 713)	1) effective spot rate of the U.S.$ 2) spot rate of the DM in terms of U.S.$ 3) spot rate of the yen in terms of U.S.$	DBB, BoJ, BoC, BdF and BoE
Lehment [1980]	April '73 – December '78	monthly	OLS	average monthly changes of the adjusted net reserve position of the DBB (p. 220)	spot rate of the DM in terms of U.S.$	DBB
Longworth [1980]	October '50 – May '62 June '70 – December '77	monthly	OLS	change in foreign exchange reserves less revaluation items and SDR allocations + change in net undelivered contracts in U.S.$ (in mill. of U.S.$) (p. 285)	month-end change in the number of Can. cents per U.S.$	BoC
Argy [1982]	March '72 – December '79	monthly	OLS	changes in the net external position of the DBB due to intervention (p. 37), changes in foreign reserves of the BoJ (p. 50), changes in the balance for official financing of the BoE (p. 59) in mill of U.S.$	effective exchange rate of the DM, the yen and the pound vis-à-vis the currencies of 15 other major countries (p. 35)	DBB, BoJ, BoE
König & Gaab [1982]	April '73 – January '82	monthly	OLS	changes in the stock of foreign exchange reserves in bill. of DM (p. 190)	change in the spot rate of the U.S.$ in terms of DM	DBB

(Table continued on next page)

(Table 1 continued)

Author	Period	Data	Estimation technique	Definition of intervention	Exchange rate	Intervening central bank
Neumann [1984]	March '74–December '81	monthly	nl OLS	DBB's direct transactions in the U.S.$/DM market (p. 237)	(log of the) spot rate of the DM in U.S.$	DBB
Bischofberger [1986]	July '73–December '80	monthly	OLS	change in total reserves minus gold (Fra., U.K., It., Jap., Can.) or in foreign exchange reserves (Ger., Swi., USA) deflated by volume of trade (p. 45)	1) effective spot rate 2) spot rate of the Swiss franc and the G-7 currencies (except U.S.$) in terms of U.S.$	central banks of the G-7 + Switzerland
Kearney & MacDonald [1986]	April '73–December '82	quarterly	OLS & IV	changes in foreign exchange reserves (p. 363)	spot exchange rate of the U.S.$ in terms of sterling (p. 350)	BoE
Gärtner [1987]	January '74–June '84	monthly	OLS & IV	percentage change of foreign exchange reserves (in mill. of U.S.$) (p. 452)	(log of the) real exchange rate of the Swiss franc in U.S.$	SNB
Gaiotti et al. [1989]	April '73–December '87	monthly	OLS & IV	Germany: interventions on the DM/$ market affecting the net external position of the DBB. Japan: total net official sales of the national currency (p. 31)	spot rate of the DM and the yen in terms of U.S.$	DBB & BoJ
Honegger [1989]	January '74–December '85	monthly	OLS & VAR	changes in foreign exchange reserves in bill. of U.S.$ (p. 160)	spot rate of the U.S.$ in terms of the currencies of each of the five countries	DBB, SNB, BoE, BoJ, BoC
Eijffinger & Gruijters [1991]	February '85–September '88	daily	OLS	"active" intervention inside the U.S.$/DM market (p. 2)	spot rate of the U.S.$ in terms of DM	DBB & FED

million of foreign exchange "for each U.S.$0.01 of discrepancy between the current value of the deutsche mark in U.S. cents", (S_t), "and its target value", (S_t^T) (p. 329). The target level of the exchange rate is based on relative prices in the Federal Republic of Germany (P_G) and the United States (P_{US}). The structural equations with standard errors in parentheses look as follows:

$$I_t = \underset{(0.093)}{0.463}\,(S_t - S_t^T) + \underset{(0.057)}{0.359}\,\dot{S}_t \qquad (2\,a)$$

$$S_t^T = 40.2 - 54.8\,(P_G/P_{US} - 1)\,. \qquad (2\,b)$$

The findings of Quirk [1977] with respect to the intervention behaviour of the Bank of Japan (BoJ) show a great deal of correspondence with those of Artus' [1976] study of the German intervention policy. Quirk, however, is not able to relate the interventions to the deviation from a target level for the yen exchange rate. Instead, the total volume of spot transactions on the Tokyo foreign exchange market and the lagged endogenous variable are significant independent variables in explaining the intervention response. A one per cent exchange rate change of the yen with regard to the U.S. dollar was accompanied on average by intervention amounting to $156 million in the month the exchange rate change occurred and $78 million thereafter. Quirk ascertained that the interpretation of the OLS estimates was not hampered by a simultaneity bias after comparing the results with those of a 2SLS estimate.

Branson et al. [1977; 1979] try to apply the asset-market model empirically to the $/DM exchange rate. To obtain consistent results, a reaction function for intervention is estimated simultaneously with an equation determining the level of the exchange rate. Branson et al. relate Germany's reserve position in period t to the reserve position in period $t-1$ and the change in the index of the $/DM exchange rate that occurred between the end of period $t-1$ and the end of period t. A rise (fall) of the $/DM exchange rate index by one point caused the Bundesbank to lean against the wind by means of purchasing (selling) $83 million when estimated over the period 1971.8–1976.12, and $180 million when estimated over the period 1971.8–1978.3.

Dornbusch [1980] assumes that central banks calculate the unanticipated depreciation of the U.S. dollar ($\dot{S}_t^{UA}$), defined as the difference between the actual depreciation of the U.S. dollar with respect to their own currencies ($\dot{S}_t$) and the depreciation that investors had already anticipated upon by demanding a risk premium on assets de-

nominated in U.S. dollars:

$$\dot{S}_t^{UA} = \dot{S}_t - (i_t^{\$} - i_t^{*}) \,. \tag{3}$$

The intervention behaviour of the major industrial countries taken as a whole (I_t) is explained rather poorly by the unanticipated depreciation of the effective exchange rate of the U.S. dollar, indicating perhaps that one or more important explanatory variables have been left out of the estimated reaction function. The main result of the estimations is, with t-values in parentheses:

$$\underset{}{I_t} = \underset{(104.8)}{1.00} + \underset{(3.22)}{0.003}\,\dot{S}_t^{UA} + \underset{(1.68)}{0.001}\,\dot{S}_{t-1}^{UA} \tag{4}$$

$$R^2 = 0.38 \quad DW = 1.81 \quad SEE = 0.05 \,.$$

For example, an unanticipated depreciation of the nominal effective exchange rate of the U.S. dollar during a quarter by one percentage point led to a cumulative intervention of 0.4 per cent of foreign net claims on the United States (in 1980: $600 million).

Lehment [1980] distinguishes two estimation periods. For the first period, April 1973–December 1975, the results show a significant proportional relationship between changes in the exchange rate of the deutsche mark in terms of U.S. dollars and changes in the reserve position of the Bundesbank. However, for the period January 1976–December 1978, there are no signs of a leaning against the wind policy. Lehment supposes that this is caused by the fact that the Bundesbank aimed its interventions at keeping the $/DM exchange rate within a certain target zone. He does not test this presumption.

Longworth [1980] is the first study to go beyond the usual verification of the leaning against the wind behaviour of the Bank of Canada (BoC). Longworth investigates whether or not there exists a "... tendency to lean more strongly when the exchange rate is moving in one direction than the other" [ibid., p. 284]. Clearly, his point of departure is a symmetrical intervention behaviour of the Canadian monetary authorities. For the 1950s and early 1960s, with Canada the only major trading nation on a floating exchange rate, Longworth finds that depreciations were opposed significantly stronger than appreciations. However, for the period June 1970–December 1977 no such asymmetries in the intervention behaviour are found. On average, the Bank of Canada bought (sold) U.S.$145 million for every cent that the Canadian dollar appreciated (depreciated) vis-à-vis the U.S. dollar in one month. Longworth notices that Artus [1976] and Quirk [1977]

found an almost equal intervention response by the DBB and the BoJ, respectively. The Canadian central bank does not appear to have tried to move the exchange rate closer to parity (Can.$1 = U.S.$1) or to purchasing power parity.

Argy [1982] presents a thorough discussion of theoretical and practical aspects of exchange-rate management comparing the experience of Germany, Japan and the United Kingdom with the use of interventions over the period March 1973 (for the UK: March 1972)–December 1979. By analyzing the differences between gross and net interventions in a year, Argy infers the main objective of a country in that year.[4] In the case of Germany and Japan in 1974 and 1975, net intervention was close to zero while gross intervention divided by exports was around 7. Of course, this indicates that the central banks have tried to smooth exchange rate changes only. Gross intervention equalling net intervention, except for the sign, points to a one-way intervention effort to oppose persistent depreciation or to rebuild reserves after a period of large sales of foreign exchange as was the case in the United Kingdom during the years 1974–76 and in 1977, respectively. Estimation results for an intervention reaction function for the United Kingdom covering the period March 1972–October 1977 look as follows, with *t*-statistics shown in parentheses:

$$I_t = \underset{(1.4)}{112.8} + \underset{(3.6)}{163.1}\,\dot{S}_t + \underset{(5.3)}{0.62}\,I_{t-1}\,, \tag{5}$$

$$R^2 = 0.53 \quad \text{Durbin's-h-statistic} = 0.00113\,.$$

It follows that every one per cent change in the effective exchange rate was accompanied on average by an intervention effort by the Bank of England (BoE) amounting to $163 million in the month the exchange rate change occurred and $266 million thereafter. For the period November 1977–December 1979, the leaning coefficient rises to 252.6. The coefficient for the lagged intervention variable becomes very small (0.08) and is no longer significantly different from zero. A regression with the percentage change of the ex post real effective exchange rate in place of the nominal effective rate yields moderately lower leaning coefficients for both periods. In the case of Germany and Japan, the reaction function can explain only a quarter of inter-

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[4] Argy [1982, p. 68] defines gross intervention as the sum of the monthly changes of reserves, irrespective of signs, divided by merchandise exports in that year. Net intervention is the same except that the sum of the monthly changes of reserves takes account of signs.

vention systematically. The coefficients for the percentage change of the effective rates are 115 and 210, respectively.

The explanatory power of the reaction functions estimated in König and Gaab [1982] over the period April 1973–July 1975 is satisfactory. The estimation results furthermore correspond for the greater part with those of the studies discussed above. However, estimates over later periods (1974–79, 1980–81) lose power dramatically.

Neumann [1984] takes up the challenge of trying to formulate and estimate an intervention reaction model which explains a considerable portion of observed Bundesbank intervention. Unlike König and Gaab [1982], Neumann has data at his disposal which give a precise coverage of the foreign exchange operations undertaken with the sole aim of influencing the exchange rate. Furthermore, Neumann applies non-linear ordinary least squares (nl OLS) as estimation technique. He tries to establish whether or not the Bundesbank shifts its priority to controlling the money stock when the uncertainty in the DM/U.S. dollar market increases. Neumann supposes that the Bundesbank buys U.S. dollars if the spot rate of the deutsche mark in terms of U.S. dollars goes beyond the target level and if the expected risk premium on DM assets increases (see (12)). The target-level specification giving the reaction function the highest explanatory power looks as follows:

$$\log S_t^T = \delta \log F_{t-1} + (1-\delta) \log S_t^{PPP} + \Delta RP_t + \mu_t \,. \qquad (6)$$

As in Artus [1976], purchasing power parity considerations (S_t^{PPP}) are taken into account. This of course comes down to stabilizing the real exchange rate. In an attempt to fight private speculation ex ante, the Bundesbank tries to compress the risk premium (RP_t). This is done by revising the target rate in accordance with increases in the expected risk premium and movements in the lagged forward rate (F_{t-1}). It appears that for the more turbulent subperiod, September 1977–December 1981, Neumann's supposition of a shift in the trade-off in favour of money control is confirmed.

Following the approach taken by Longworth [1980], the empirical research in Bischofberger [1986] is aimed at establishing whether the central banks of the G-7 countries and Switzerland employed their intervention policy of leaning against the wind symmetrically across periods of depreciation and appreciation of their own currencies vis-à-vis the U.S. dollar and of the effective exchange rate of their own currency. Bischofberger chooses to deflate the monthly change in a country's foreign exchange reserves by the sum of merchandise imports and exports in the current and eleven previous months. He does

this to make the estimated coefficients and thus the intervention efforts comparable across countries. Therefore, the implicit assumption is that the more open an economy is, the more reluctant a central bank will be to short-term exchange rate fluctuations. In an attempt to detect (ir)regularities in the intervention behaviour of the individual countries, the 90 monthly observations have been divided into four categories according to the direction of change of the exchange rate in period t and $t-1$ straightforwardly; trend and non-trend depreciations and appreciations are thus distinguished.

$$I_t = \alpha_0 + \alpha_1 A_1 \dot{S}_t + \alpha_2 A_2 \dot{S}_t + \alpha_3 A_3 \dot{S}_t + \alpha_4 A_4 \dot{S}_t + \mu_t , \qquad (7)$$

with: $A_1 = 1$ in case of trend appreciation, 0 otherwise;
$A_2 = 1$ in case of non-trend appreciation, 0 otherwise;
$A_3 = 1$ in case of trend depreciation, 0 otherwise;
$A_4 = 1$ in case of non-trend depreciation, 0 otherwise.

To be able to make comparisons across time, subsamples consisting of 30 observations each are created.[5] The three subsamples are July 1973–December 1975, January 1976–June 1978 and July 1978–December 1980. The Bundesbank appears to have carried out its interventions symmetrically. The intervention-trade ratio for a one per cent change in the effective exchange rate of the deutsche mark is 0.0023(!) on average for all four categories of intervention. As König and Gaab [1982] experienced, the explanatory power of the estimated reaction function for the Bundesbank declines over time. The estimated reaction functions for the Banque de France (BdF) and the Banca d'Italia have low explanatory power and indicate that there was no systematic leaning against the wind behaviour. For the sample as a whole, the Bank of England is found to have assigned systematically more weight to countering depreciations of the effective exchange rate of the pound and depreciations of the pound vis-à-vis the U.S. dollar. However, the estimation results for the subsamples indicate that both trend and non-trend appreciations of the pound were a matter of concern of the British monetary authorities as well. The Bank of Japan appears to have acted in a slightly asymmetrical way. The variable capturing non-trend depreciations of the yen vis-à-vis the U.S. dollar has a coefficient significantly different from zero indicating at a leaning *with* the wind behaviour. The directives of the Canadian Exchange

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[5] This may cause the number of observations assigned to each of the four categories to become too small to be able to present meaningful estimates. These numbers are not reported by Bischofberger [1986].

Fund obliged the Bank of Canada to follow grosso modo the same intervention pattern as the Bank of Japan whereby sales and purchases of foreign currency were carried out more systematically and on a larger scale when measured by the intervention-trade ratio. Apart from the regularity in foreign currency swap operations which were carried out to manage the liquidity position of the private banking system in Switzerland across the entire sample, Bischofberger [1986] only finds the second subsample to show a systematic pattern of foreign exchange intervention. The Swiss National Bank appears to have tried to resist appreciations of the Swiss franc with respect to the U.S. dollar lasting longer than one month on the one hand and to have supported depreciations which ex post were found to have lasted no longer than one month on the other hand, both with particularly high intervention-trade ratios. The intervention behaviour of the monetary authorities of the United States can be explained by means of a linear reaction function only for the last two subsamples. It can be concluded that for this period their efforts were only directed at curbing the rise of the effective exchange rate of the U.S. dollar.

Kearney and MacDonald [1986] study the intervention behaviour of the Bank of England. They make a distinction between day-to-day dealings in foreign exchange to smooth transient fluctuations on the one hand, and interventions "... on a scale sufficient to maintain the rate of exchange at a level which differs from that which would otherwise have cleared the foreign exchange market" (p. 348) on the other hand. Quarterly data are used to test empirically whether the latter category of interventions was guided by a systematic leaning against the wind policy. The OLS estimation result for the period April 1973–December 1982 looks as follows, with *t*-values in parentheses:

$$I_t = \underset{(0.46)}{-202.18} - \underset{(2.49)}{54.582}\,(S_t - S_{t-1}) + \underset{(3.10)}{0.466}\,I_{t-1} \qquad (8)$$

$$\bar{R}^2 = 0.34 \qquad DW = 1.88\,.$$

It follows that on average the Bank of England bought (sold) $ 54.6 million for every pence the value of the U.S. dollar dropped (rose) during the month the exchange rate change occurred and $ 47.6 million thereafter. An IV estimation renders a higher but insignificant leaning coefficient. A target exchange rate term defined analogously to that in Artus [1976] is insignificant.

Gärtner [1987] challenges the ruling consensus that central banks only employ a leaning against the wind policy when foreign exchange

market intervention is concerned. He argues that, as large and persistent medium-term movements in the exchange rates are of major concern to international business, exchange rate targeting should show up in the intervention reaction function as well. Before presenting an alternative specification of a reaction function for the Swiss National Bank (SNB) which meets with the apparent shortcomings of earlier investigations, Gärtner criticizes the way in which other studies deal with the simultaneity bias in the reaction function. He claims to have found an appropriate solution for this problem: employing the instrumental variables estimation technique using the percentage rate of change of the real $/DM exchange rate as an instrument to replace the percentage rate of change of the real exchange rate of the U.S. dollar vis-à-vis the Swiss franc. Indeed, as the real $/DM rate is a cross-rate of the real $/Sfr rate, movements in both rates are correlated by definition. However, a direct consequence is that intervention by the German and Swiss central banks will be correlated as well. Therefore, Gärtner's assertion that changes in the real $/DM rate do "...not itself respond in any relevant fashion to Swiss intervention" [1987, p. 447] is a faulty one. This holds in particular when the Swiss National Bank subscribes to the conclusion reached in the following section that *coordinated* interventions conveying a news content constitute the only sort of interventions that have a chance to affect the rate of change of an exchange rate. Therefore, the real $/DM rate is not a proper instrument for the reaction function and the estimation results will not be reported. An interesting aspect of the investigations by Gärtner is the flexible formulation of the reaction function. Not only is a distinction made between the directions of change in the real exchange rate during a month; the possibility is left open that the central bank takes into account the state in which a currency is, i.e. whether the real Sfr/$ rate is overvalued or undervalued. Thus, four cases are created.[6] It is found that appreciations of the real exchange rate occurring while the Swiss franc was overvalued were opposed most strongly. Appreciations of the real exchange rate taking place while the Swiss franc was undervalued were tolerated. Analogous leaning against destabilizing wind is detected for depreciations of the Swiss franc vis-à-vis the U.S. dollar.

Gaiotti et al. [1989] try "...to ascertain whether the intervention policies of 1985–87 entailed a departure from past practices..."

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[6] Unlike Bischofberger [1986], Gärtner reports on the number of observations applying to each case.

(p. 21). Their estimations cover the period 1974.4–1987.12 or subperiods within this sample using monthly data. The estimating equation is obtained by substituting the equation which explains movements in the target exchange rate S_t^T, equation (2b) above, into the actual intervention reaction function. The intervention data Gaiotti et al. use are not very detailed. To account for changes in the reserve position of a central bank (I_t) that do not directly result from interventions in the foreign exchange market, the trade balance (TB_t) is included as an explanatory variable in the reaction function. This is the main difference from the approach taken by Artus [1976]. The main IV estimation results look as follows, with t-values in parentheses, for the Deutsche Bundesbank:

$$I_t = \underset{(-4.28)}{-1{,}413.1} + \underset{(3.12)}{1{,}479}\,(P_{GER}/P_{US} - 1) + \underset{(0.44)}{17.96}\,TB_t + \underset{(3.77)}{2{,}603.8}\,S_t + \underset{(3.46)}{169.44}\,\dot{S}_t \qquad R^2 = 0.30 \qquad DW = 1.83 \qquad (9\,a)$$

and for the Bank of Japan:

$$I_t = \underset{(-4.24)}{-3{,}715.4} + \underset{(3.08)}{3{,}148.7}\,(P_{JAP}/P_{US} - 1) + \underset{(2.63)}{150.74}\,TB_t + \underset{(3.78)}{6{,}974.8}\,S_t + \underset{(2.03)}{189.34}\,\dot{S}_t \qquad R^2 = 0.39 \qquad DW = 1.69\,. \qquad (9\,b)$$

The leaning against the wind behaviour of the Bundesbank appears to have been stable throughout the period. From the IV estimates it follows that the German central bank on average bought (sold) $169 million for every one per cent appreciation (depreciation) of the deutsche mark vis-à-vis the U.S. dollar during one month. However, the steady appreciation of the U.S. dollar from March 1980 until February 1985 was accompanied by a more than average intervention effort by the Bundesbank. The estimated coefficient for the variable capturing the leaning against the wind intervention by the Bank of Japan is larger ($189 million) than that of the Bundesbank. Moreover, the Japanese central bank intervened significantly less than average during the period of U.S. dollar appreciation mentioned earlier. Furthermore, Gaiotti et al. [1989] find that the Bank of Japan from the middle of 1986 onwards rigidly tried to hold on to the prevailing exchange rate level. The reported IV estimates of the leaning coefficients are significantly higher than the ones obtained with OLS. This can be explained by the fact that the former method accounts for the negative correlation between $\dot{S}_t$ and I_t, while the latter does not. In

view of the frequency of the data, one wonders whether the percentage rate of change of the spot rate from one period (month) to another ($\dot{S}_t$) can capture the leaning against the wind character of the interventions adequately. A dummy variable accounting for the coordinated interventions following the Plaza Agreement enters the estimated reaction functions of both the Bundesbank and the Bank of Japan with a coefficient significantly different from zero. This indicates that the concerted action in October 1985 is one without precedent in the post Bretton Woods era.

Honegger [1989] wants to let the data determine which explanatory variables have to be included in the intervention reaction function for the central banks of Canada, Germany, Japan, Switzerland and the United Kingdom. He applies the vector autoregression (VAR) estimation technique to determine for each of the five countries whether or not lagged values of the level of intervention, the unemployment rate, the inflation rate, the percentage change of the exchange rate and the deviation of the exchange rate from purchasing power parity are significantly correlated with the monthly level of intervention for the period January 1974–December 1985. For all the respective central banks no other variable than lagged intervention and the percentage change of the exchange rate of the home currency vis-à-vis the U.S. dollar appear to be correlated with intervention. Honegger, however, argues that while a lasting deviation of a country's effective exchange rate from purchasing power parity (PPP) is far more damaging for the domestic economy than short-term exchange rate volatility, it should at least appear from the reaction functions that central banks take into account whether or not a currency is over- or undervalued and act differently when the exchange rate moves towards PPP as compared to cases in which the exchange rate moves away from the rate according to PPP. Honegger contends that, as actual monthly foreign and domestic inflation rates (necessary to compute the PPP rate) are available only with a certain lag, it is unknown whether a currency is over- or undervalued during a particular month. In spite of that, to obtain the ex ante PPP rate, Honegger computes forecasts on the assumption that the equilibrium exchange rate follows a first-order autoregressive process. Four variables are calculated, each representing the percentage change of the home currency vis-à-vis the U.S. dollar during one month in discrete cases:

V_1 = appreciation during undervaluation;
V_2 = depreciation during overvaluation;

V_3 = depreciation during undervaluation;
V_4 = appreciation during overvaluation.

OLS estimation results look as follows, with t-values in parentheses, for the Deutsche Bundesbank:

$$I_t = \underset{}{-0.006} - \underset{(4.36)}{0.515\,V_1} - \underset{(1.22)}{0.207\,V_2} - \underset{(1.65)}{0.501\,V_3} - \underset{(4.64)}{0.872\,V_4} + \underset{(1.10)}{0.083\,I_{t-1}};$$
$$\underset{(0.86)}{}$$

$$R^2 = 0.26 \quad \text{Durbin's h} = -4.93 \quad \text{SER} = 0.034 \qquad (10\text{a})$$

and for the Bank of Japan:

$$I_t = \underset{(0.26)}{0.002} - \underset{(0.32)}{0.064\,V_1} - \underset{(2.52)}{0.515\,V_2} - \underset{(1.29)}{0.509\,V_3} - \underset{(5.17)}{1.022\,V_4} + \underset{(4.25)}{0.304\,I_{t-1}};$$

$$R^2 = 0.34 \quad \text{Durbin's h} = -2.65 \quad \text{SER} = 0.037. \qquad (10\text{b})$$

The coefficients in the reaction function for the Deutsche Bundesbank only differ significantly from zero in those months in which the deutsche mark appreciated with respect to the U.S. dollar. It has to be stressed that this finding not only applies to months in which the deutsche mark was overvalued (V_4), but also to months in which the deutsche mark was undervalued (V_2), albeit with a smaller leaning coefficient. It is unclear how to derive the nominal amount of intervention for each percentage point the exchange rate changed in each of the four cases. According to Honegger, from these estimation results the Bundesbank appears to have aimed its intervention decisions at least partly at enhancing the competitiveness of German industry. For the Bank of Japan leaning against the wind behaviour is found only during months in which the yen was overvalued. Most noticeable in this respect is the systematic selling of foreign exchange in return for yen when the yen "threatened" to move towards the (computed) equilibrium value. The Bank of Canada appears to have carried out its interventions symmetrically across all four cases. The amount of intervention during months of appreciation was three times as large as during months of depreciation. For the Bank of England the results suggest that interventions were mainly guided by the pursuit of domestic price stability. The operations in the foreign exchange market were directed one-sidedly at opposing depreciations of the pound vis-à-vis the U.S. dollar. The estimation results for the Swiss National Bank are similar to the ones found by Gärtner [1987].

Eijffinger and Gruijters [1991] have daily data of intervention by the Bundesbank and the Federal Reserve System at their disposal.

This makes it possible to test a second intervention strategy: countering erratic fluctuations and leaning against the wind over shorter periods than one month. To take account of exchange rate movements which take place during a day, Eijffinger and Gruijters include in their estimation the opening, fixing, and closing rates of every trading day at the Frankfurt foreign exchange market. These variables are indicated by S_t^P, S_t^F and S_t^U, respectively. It appears that on average one fifth of the Bundesbank and Federal Reserve interventions taken as a whole were directed at minimizing the difference between the spot rate and the five-days moving average of the opening, fixing and closing rate of the U.S. dollar in terms of deutsche mark. For September 1985, estimation results indicate that the Bundesbank pursued a leaning *with* the wind policy. A closer inspection of the data revealed that all observed U.S. dollar sales were carried out after the establishment of the Plaza Agreement had shifted the market sentiment in favour of a depreciation of the U.S. dollar. The coordination of exchange market intervention by the Bundesbank and the Federal Reserve System is investigated by adding intervention by the Federal Reserve as an extra explanatory variable to the Bundesbank's reaction function. The estimated coordination coefficient is significantly different from zero in five out of eight months in which both central banks intervened. However, its value is unstable indicating a divergent degree of coordination. To test the effect of exchange market uncertainty on interventions the smoothing coefficient is adjusted for the variance of the opening, fixing and closing rates of the U.S. dollar in terms of the deutsche mark in the past five days. The estimation results for the reaction function of the Bundesbank's interventions (I_t^{DBB}) in October 1987 are as follows, with t-values in parentheses

$$I_t^{DBB} = \underset{(-0.10)}{-0.003} - \underset{(-5.47)}{1{,}321.7\,\sigma_5^2}\left[S_t^P - 1/15\sum_{n=1}^{5} S_{t-n}^{P/F/U}\right], \qquad (11)$$

with $$\sigma_5^2 = \sum_{n=1}^{5}\left[S_{t-n}^{P/F/U} - 1/15\sum_{n=1}^{5} S_{t-n}^{P/F/U}\right]^2, \quad \bar{R}^2 = 0.580 \quad DW = 1.760.$$

Eijffinger and Gruijters [1991] find that in months with large exchange rate fluctuations the smoothing coefficient as well as the explanatory power of the reaction function are larger than in months with small fluctuations. This indicates that the Bundesbank and the Federal Reserve System take their responsibility and do not retreat when the uncertainty grows, contrary to the empirical findings of Neumann [1984].

IV. Effectiveness of Exchange Market Intervention

In this part we will summarize the results of empirical research carried out to ascertain the effectiveness of foreign exchange market intervention undertaken since 1973. Following the approach taken by Loopesko [1984] and Humpage [1986], a number of channels can be distinguished through which the exchange rate can be influenced.

A purchase (sale) of foreign exchange by a central bank leads, ceteris paribus, to an increase (decrease) in the reserve position of the private banking system as a whole. The induced loosening (tightening) of the domestic money market results in an increase (decrease) in the money stock. In most economic models a depreciation (appreciation) of the domestic currency is the immediate consequence. Nearly all empirical investigations disregard this monetary channel because it can be argued that this channel applies to monetary policy rather than exchange rate policy. Of course, this argument may be arbitrary.

To keep the money stock from increasing (decreasing), the monetary authorities can sterilize the effect of the exchange market intervention by selling (buying) short-term domestic assets to (from) the banking system leaving the monetary base of the country unchanged. Theoretically, sterilized purchases and sales of foreign exchange can have an impact on the exchange rate. Loopesko distinguishes three possible channels. In the portfolio-balance model it is assumed that risk-averse wealth holders diversify their portfolios across assets denominated in different currencies. When wealth holders do not view otherwise identical government bonds denominated in currency A and currency B as perfect substitutes, a disturbance of the portfolio-balance caused by a sterilized purchase of currency B carried out by the central bank of country A will, ceteris paribus, lead to a rise in the spot exchange rate (S_t) of currency B in terms of currency A. The level of the risk premium on government bonds denominated in currency B (RP_t^B) can be defined as:

$$RP_t^B = (i_B - i_A)_t - (S_t - E_t S_{t+1}) \,. \tag{12}$$

E_t is the expectational operator conditional on the available information at time t. The sale of short-term government bonds denominated in currency A, necessary to leave the monetary base in country A unchanged, induces a rise in i_A and an excess demand for foreign securities by the investors who try to rebalance their portfolios. However, an inducement to switch their assets denominated in currency A for assets denominated in currency B is required: a *depreciation* of

currency A in terms of currency B restores portfolio-balance by lowering the risk premium on government bonds denominated in currency B, and by increasing the value of government bonds denominated in currency B in terms of currency A.

Besides the portfolio-balance channel, two other channels are distinguished by which sterilized interventions can affect the exchange rate. The market-efficiency channel implies that the central bank can "[focus] the attention of the public on neglected information that is germane to exchange rate determination" [Loopesko, 1984, p. 258]. It must be noted that in our opinion it is very hard for the central bankers to establish the market inefficiencies with certainty. The superior-information channel corresponds with what we call the expectations channel. By providing the market with new information or a signal about the future course of the exchange rate or of monetary policy, the exchange rate can be expected to change immediately after the intervention. Notably, supporters of the asset market view of exchange rates see this as the main channel through which interventions can affect the exchange rate.

Attention has been paid to the effectiveness of interventions via the portfolio-balance channel because this channel, if operative, constitutes an independent tool of monetary policy. However, the enormous growth in financial market turnovers during the last decade has diminished the potential for central banks to cause a significant imbalance in wealth holders' portfolios. For this reason current research focusses more on the expectations channel.

As was argued, the portfolio-balance channel can only be effective if the risk premium (RP_t) in (12) does not equal zero. Problems arise, however, when one wants to calculate the risk premium. Various attempts have been made using different kinds of expectations formations (see, on the problem of estimating econometrically the portfolio-balance model, Tryon [1983] and Weber [1986]). Another complication lies in the fact that the effect of central bank interventions is absorbed in the movements of the exchange rate immediately. To get a clear view of the actual effectiveness one should be able to compare these movements with the fluctuations in the exchange rate that would have occurred in the absence of intervention. Furthermore, it can be argued that the estimations are rather partial as most of the time intervention will be accompanied by other measures of monetary policy, for instance interest rate policy (see, on the relative importance of intervention determining exchange rates during the period 1985–88, Obstfeld [1988]).

Table 2 – *Effectiveness of Foreign Exchange Market Intervention: Some Characteristics of the Studies Reviewed*

Author	Period	Data	Estimation technique	Definition of intervention	Exchange rate	Intervening central bank
Portfolio-balance channel						
Branson et al. [1977] Branson et al. [1979]	August '71 – December '76 August '71 – March '78	monthly	2SLS	international reserves of Germany (in U.S.$) minus cumulated SDR allocations (p. 323)	spot rate of the DM in U.S.$ terms, index 1970 = 100	DBB
Obstfeld [1983]	January '75 – October '81	monthly	2SLS	change in the DBB's net foreign assets minus the change in foreign reserve valuation (p. 185)	U.S.$ in terms of DM (p. 186)	DBB
Loopesko [1984]	May '75 – November '81	daily	OLS	interventions of the individual G-7 countries (in mill. of U.S.$), more precise definition unknown (p. 270)	log of the spot rate of the G-7 currencies in terms of the U.S.$	central banks of the G-7 countries
Rogoff [1984]	March '73 – December '80	weekly	2SLS	changes in the Can. Exchange Fund account, SDR allocations and bookkeeping valuation effects netted out (p. 148)	log of the spot rate of the U.S.$ in terms of Can.$	BoC
Danker et al. [1985]	February '75 – December '81	monthly	nl 2SLS	no intervention data used	spot rate of the DM and the yen in terms of U.S.$, spot rate of the U.S.$ in Can.$	model is estimated for Japan, Germany and Canada
Kearney & Mac-Donald [1986]	April '73 – December '82	quarterly	OLS & IV	changes in foreign exchange reserves (p. 363)	spot exchange rate of the U.S.$ in terms of sterling (p. 350)	BoE

(Table continued on next page)

(Table 2 continued)

Author	Period	Data	Estimation technique	Definition of intervention	Exchange rate	Intervening central bank
Portfolio-balance and expectations channel						
Dominguez & Frankel [1990]	November '82–December '87	daily	IV	DBB: 'active interventions' aimed at influencing the U.S. $/DM spot rate. Fed & Treasury: constructed intervention series from Fed publications (p. 3)	log of the spot rate of the DM in terms of the U.S. $	DBB & FED
Dominguez [1990]	January '85–December '87	daily	OLS	DBB and Fed data: see Dominguez & Frankel. Dummy variable for BoJ-intervention constructed by the author (p. 130)	spot rate of the DM and the yen in terms of U.S. $ (p. 140)	DBB, FED, BoJ
Expectations channel						
Humpage [1988]	August '84–August '87	dummies with value 1 on days the Fed intervened and 0 otherwise	OLS	"Intervention dummies are constructed from internal documents on U.S. intervention" (p. 4)	1) log of the spot rate of the U.S. $ in terms of DM 2) log of the spot rate of the U.S. $ in terms of yen	FED
Eijffinger & Gruijters [1989]	February '85–August '88	daily	OLS	active intervention inside the U.S. $/DM market aimed at influencing the spot rate of the U.S. $ in DM (in bill. of DM) (p. 2)	spot rate of the U.S. $ in terms of DM	DBB & FED

The main characteristics of the empirical studies we will discuss below are summarized in Table 2.

Branson et al. [1977; 1979] estimate a reduced-form portfolio balance model. Movements in the spot rate of the deutsche mark in terms of U.S. dollars (S_t) are related to movements in U.S. and German stocks of money ($M1_t^{US}$, $M1_t^{G}$) and stocks of net foreign assets (FP_t^{US}, FP_t^{G}). Sterilized foreign exchange market interventions have an impact on the volume of a country's net foreign assets, but leave the money stock unchanged. Thus, it is possible to detect the effect of such interventions without having the problem of finding a proxy for the expected exchange rate movements. Consistent estimates look as follows, with t-values in parentheses:

$$\begin{aligned} S_t = &-4.852 - 0.062\,M1_t^{G} + 0.092\,M1_t^{US} + 0.676\,FP_t^{G} - 0.398\,FP_t^{US}; \\ &(-0.1)\quad(-1.7)\qquad(2.8)\qquad(1.7)\qquad(-1.9) \\ &\bar{R}^2 = 0.937 \qquad DW = 1.349 \qquad RHO = 0.868\,(14.0)\,. \end{aligned} \tag{13}$$

RHO denotes the estimated first-order autocorrelation. All coefficients have the correct sign. From a point estimate in Branson et al. [1977], it can be derived that a sterilized purchase by the Bundesbank of $1 billion on average caused the deutsche mark to depreciate by 0.185 cent. Comparing Branson et al. [1977] with Branson et al. [1979], however, leads one to conclude that the results are unstable.

To find some evidence on the extent to which sterilized intervention was practiced by the Bundesbank during 1975–81, Obstfeld [1983] estimates a domestic credit reaction function. The estimated coefficients indicate that only a small fraction of any change in reserves was allowed to affect the monetary base. In contrast to Branson et al. [1977; 1979], Obstfeld focusses on a structural portfolio balance model of German asset markets. The estimation results indicate that home and foreign demand for DM-denominated bonds only adjusted slowly to their long-run levels. To assess the effects of sterilized as compared to non-sterilized intervention on the exchange rate, the empirical model is simulated under the assumption that agents have perfect foresight concerning future exchange rate movements. As many events that impinge on the exchange rate are in fact unanticipated, the historical exchange rate path is not a proper reference for the simulation results. Therefore, the results of a simulation giving the exchange rate's perfect-foresight path in the absence of intervention serve as a benchmark. The results of the simulation experiments imply that a foreign exchange sale by the Bundesbank that decreases the

German monetary base by DM 13.25 billion (in 1979: 10 per cent) causes an immediate 3.0 per cent appreciation of the deutsche mark vis-à-vis the U.S. dollar relative to its benchmark value. By contrast, the simulated effect on the exchange rate of an unanticipated but transitory sale of DM 13.25 billion which is accompanied by an open market purchase of DM-denominated bonds of equal proportion by the German central bank is a mere 0.04 per cent. The apparent ineffectiveness in simulation experiments with monthly data do, however, "... leave open the possibility that sterilised foreign exchange market intervention has significant but short-lived exchange rate effects that disappear within a month" [Obstfeld, 1983, p. 185].

Loopesko [1984] constructs a series for realized one-day foreign exchange market profits, r_t, taking into account the usual two-day lag in delivery on spot foreign exchange contracts:

$$r_{t-2,t+1} = (i_t^{US} - i_t^*) - (S_{t-1} - S_{t-2}) \,. \tag{14}$$

S is the logarithm of the spot rate of a G-7 currency in terms of the U.S. dollar, i^{US} and i^* are overnight U.S. dollar and G-7 currency Euro deposit rates, respectively. Realized profits calculated this way reflect both the expected risk premium and any spot rate forecast error. The joint hypothesis of perfect substitutability of assets denominated in different currencies and of the 'efficient' working of the foreign exchange market is rejected because previously observable variables (e.g. cumulated interventions, lagged values of realized profits and the exchange rate) proved to be significant determinants of realized profits. The results of a second (F-)test lead Loopesko to conclude that "... the predictable component of realized profits can be identified with a risk premium, and hence that sterilized intervention can affect the exchange rate through a portfolio balance channel" (p. 267). However, interventions are only one out of many factors that determine demand and supply conditions on the foreign exchange market and therefore changes in the risk premium. Loopesko's investigation of the 'extra effectiveness' of coordinated interventions is hindered by a lack of data as well as difficulties in interpreting the data. She finds some evidence of a more than proportionate effect of coordinated U.S. and narrowly defined German intervention.

Rogoff [1984] expects the risk premium on assets denominated in Canadian dollars to be positively correlated with the relative supply of Canadian dollar (A_t)- versus U.S. dollar (A_t^*)-denominated outside assets, both including the monetary base:

$$(i_t^{CAN} - i_t^{US} - \Delta S_t^e) = \alpha_0 + \alpha_1 (A_t / S_t A_t^*) + \mu_t \,. \tag{15}$$

He supposes that expectations are formed rationally. This enables him to replace the expected exchange rate change by the ex post exchange rate change:

$$S_{t+1} = S^e_{t+1} + \Theta_{t+1}\,, \tag{16}$$

where Θ_{t+1} is a forecasting error which is uncorrelated with any information dated period t or earlier. The very disappointing estimation results are accompanied by the "plausible interpretation (...) that there is a time-varying exchange risk premium but one that cannot be affected by sterilized intervention" (p. 141).

Danker et al. [1985] study the degree of substitutability of bonds denominated in deutsche marks, Japanese yens, and Canadian dollars with those in U.S. dollars. Danker et al. argue that direct estimation of the asset-demand equations forming the portfolio-balance model "...may not yield accurate estimates of the degree of substitutability when the true degree of substitutability is quite high" (p. 1). Therefore, inverted bond-demand equations are estimated with non-linear two-stage least squares (nl 2SLS). The dependent variable in these equations is the risk premium. Both under the assumption of static as well as rational exchange rate expectations, perfect substitutability implies that the risk premium should be uncorrelated with explanatory variables suggested by the portfolio-balance model (short-term interest rate differentials, real income, real wealth and stocks of bonds). For Germany the estimation results based on monthly data clearly point to the rejection of perfect substitutability. The results are, however, inconsistent with the portfolio-balance model. The same applies to the results for Canada obtained with quarterly instead of monthly data. For Japan, when assuming rational expectations, the hypothesis that all the coefficients in the inverted bond equation are equal to zero is not rejected using monthly data. Having established this, Danker et al. report estimation results for the original bond-demand equations. They only consider whether (the sign of) the estimated parameters of these equations are consistent with the portfolio-balance model. Perhaps the disappointing results of earlier empirical investigations have prevented them from formal hypothesis testing. The consequence is that "the degree of success obtained is largely a matter of judgment" (p. 12).

Kearney and MacDonald [1986] replicate the study by Obstfeld [1983]. Central to their investigations is a portfolio-balance model for the United Kingdom estimated with quarterly data for the period 1973.2–1982.4. They examine the potency of sterilized and non-steril-

ized interventions carried out by the Bank of England by looking at the results of various policy simulations with the model. Their results contrast with Obstfeld's findings for Germany. A non-sterilized sale of U.S. dollars worth £10 billion (in 1976: 10 per cent of the U.K. monetary base) causes the pound to appreciate 7.9 per cent vis-à-vis the U.S. dollar. Furthermore, a sterilized sale of equal magnitude is to raise the value of sterling by 3.2 per cent. Kearney and MacDonald contend that the effectiveness of a sterilized intervention not only depends upon the degree of substitutability between domestic and foreign assets. Besides that, they emphasize the importance of the degree of capital mobility whereby the instantaneous achievement of portfolio balance is regarded as a necessary and sufficient condition for perfect capital mobility.[7] Kearney and MacDonald impute the effectiveness of sterilized intervention appearing from the simulation results for the U.K. to the restrictions on capital mobility in the 1970s.

The goal of Dominguez and Frankel [1990] is to disentangle the influence of the portfolio and the expectations channel. Dominguez and Frankel do not "invoke the methodology of rational expectations" (p. 9). Instead, they "measure expectations of the future spot exchange rate by means of survey data on the forecasts of market participants" (p. 3).[8] As was argued at the beginning of this section, sterilized interventions are effective if they are able to change the risk premium. As the expected exchange rate change is a crucial component of the risk premium, Dominguez and Frankel try to establish the impact of publicly known intervention and those interventions carried out anonymously on market participants' expectations:

$$\hat{S}^e_{t+k} - S_t = \alpha_0 + \alpha_1 (S_{t-j} - S_t) + \alpha_2 NEWS_t + \alpha_3 REPI_t + \mu_t \,, \tag{17}$$

where $\hat{S}^e_{t+k}$ is the log of the k-days-ahead expectation for the \$/DM spot rate. It is supposed that investors expect the trend in exchange rate movements over the previous j days to carry on during the following k days. Furthermore, investors are expected to redress their expectations when it becomes known that central banks change their exchange rate policy. The dummy variable *NEWS* captures this effect.

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[7] Of course, the degree of capital mobility determines to a large extent the degree of substitutability between domestic and foreign assets also.

[8] This method is open to question because survey data do not have to correspond with market expectations. Market participants may be interested in masking their actual expectations. For a survey of the pros and cons of using survey data, see Takagi [1991].

The dummy variable *REPI* is multiplied by the amount of intervention reported in the newspapers to account for the effect of discrete interventions. Consistent estimates are obtained by replacing variables which cause simultaneity by instrumental variables that are exogenous but do, at least partly, explain the endogenous variables. Estimation results for the period October 1982–October 1984 are not very interesting. As is well known, the monetary authorities in the U.S. hardly intervened during that period. For the period October 1984–December 1987 it appears from the estimation results that "newspaper reports of prospective intervention in support of the dollar (...) tend[ed] to lower expectations of the future $/DM exchange rate" [Dominguez and Frankel, 1990, p. 18] by 0.005 per cent on average. When measured on the day before the survey, intervention, expressed as a per cent of wealth, is a statistically significant determinant of the risk premium on DM-denominated assets. This leads Dominguez and Frankel to conclude that over the period considered sterilized interventions were effective. In an attempt to quantify the effects they carry out some tentative calculations. On the assumption that interest rates in Germany and the United States are held constant an intervention not known publicly has no effect on the risk premium. The effect on the spot rate is in proportion to the total reserve money supplied to the banking system by the Bundesbank. A $100 million non-sterilized intervention thus represents an exchange rate change of 0.079 per cent (in 1987). The change in the spot rate caused by a sterilized intervention of the same amount is smaller but is nonetheless not zero. The calculated exchange rate effect of a publicly known intervention is far greater. The level of the risk premium on DM assets is affected. This leads investors to reallocate their portfolios. In the absence of expectations with an extrapolating character and of induced interest rate changes, the exchange rate change amounts to 2.4 per cent.

Dominguez [1990] investigates whether ex post one-day, thirty-day and ninety-day excess returns in the $/DM and $/yen market are related to unilateral and coordinated intervention by the Bundesbank, the Federal Reserve System and the Bank of Japan.[9] Five distinct episodes are estimated: January 1985–March 1985, September 1985–December 1985, September 1986–January 1987, February 1987–June

[9] It should be noted that Dominguez [1990] constructs for the three-year sample period a dummy variable set to unity for those days on which the Bank of Japan was to her opinion in the market and zero otherwise. Despite these questionable data she draws some tentative conclusions on coordinated interventions by the three central banks.

1987 and October 1987–December 1987. Dominguez claims to focus on the possible signalling effect of official intervention, i.e. the capacity of intervention to influence exchange rates by providing information about the future conduct of monetary policy. Although she states that this effect does not rely on the existence of a risk premium her method for estimating the signalling effect does. The estimation results for the five periods of coordinated G-3 intervention, however, indicate that the expectations channel was the main channel through which intervention affected the excess returns. For each subperiod the results are in line with what could be expected on the basis of Dominguez' description of the policy announcements made by the G-3 monetary authorities and the press accounts reflecting how these announcements were received by exchange market participants. For example, the Plaza Agreement was understood by the market to be specifically initiated by the United States. This was seen as a definitive break from the previous policy and the market was very alert to U.S. intervention. By contrast, no particular attention was paid to Bundesbank intervention immediately after the Plaza Agreement. The German central bank had already intervened on a large scale in the first quarter of 1985 and its intentions apparently had not changed since then. The estimation result for the equation relating the ex post one-month \$/DM excess return, taking into account the usual two-day lag in delivery on spot contracts, $r_{t-2,t+21}$, to the interventions of three days ago for the period September 1985–December 1985 is reported here, with t-values in parentheses:

$$r_{t-2,t+21} = \underset{}{-40.44} \underset{(-5.18)}{-\ 0.12\, I_{t-3}^{FED}} \underset{(-2.55)}{-0.16\, I_{t-3}^{DBB}} \underset{(-1.81)}{-0.51\, I_{t-3}^{C}} \qquad (18)$$

$$\underset{(-2.16)}{}$$

$$R^2 = 0.09\ .$$

The excess return is relating to Euro currency deposits with a time to maturity of one month, i.e. twenty-one trading days. Analogous to Eijffinger and Gruijters [1989], Dominguez defines coordinated intervention (I^c) observations as the sum of Fed and Bundesbank intervention observations on those days at which both banks intervened in the same direction. A coordinated sale of \$1 million on average increased the annualized \$/DM return differential by 51 basis points. The results change from subperiod to subperiod. In some instances, statistically significant but wrongly signed coefficients are obtained reflecting the fact that the interventions were not accompanied by credible policy announcements. The fact that "coordinated intervention had a signif-

icantly different and longer-term influence on market expectations than did unilateral intervention over the three-year period examined" [Dominguez, 1990, p. 158] indicates that it was not the size of intervention that counted, which is compatible with the portfolio-balance channel, but the source of intervention pointing to the relevance of the expectations channel.

In the analysis of Humpage [1988] it is not the volume of intervention that counts but the mere fact that the Federal Reserve Bank did intervene. To emphasize the search for the "news"-effect of interventions, Humpage makes a distinction, with the aid of dummy variables, between initial intervention, which he defines as intervention carried out following a period of at least five days without intervention on the one hand, and subsequent intervention defined as the complement of the former type on the other hand. For the period August 1984–August 1987 Humpage distinguishes three estimation periods in which the attitude of the Federal Reserve System towards intervention showed fundamental differences. Initial purchases of deutsche mark and yen directly following the Plaza meeting (represented by the dummy variables D^1 and D^3, respectively) significantly contributed to a depreciation of the U.S. dollar against the deutsche mark and the yen, respectively. Subsequent intervention (represented by the dummy variables D^2 and D^4, respectively) did not produce a significant effect:

$$S(DM/\$)_t = \underset{(-6.455)}{-0.052\, D_t^1} + \underset{(0.824)}{0.002\, D_{t-1}^2} + \underset{(1{,}003.3)}{0.999\, S(DM/\$)_{t-1}}\,, \tag{19a}$$

$$S(yen/\$)_t = \underset{(-4.996)}{-0.027\, D_t^3} - \underset{(-0.101)}{0.0002\, D_{t-1}^4} + \underset{(5{,}272.1)}{0.999\, S(yen/\$)_{t-1}}\,. \tag{19b}$$

Initial intervention carried out as a consequence of the Louvre Agreement did not have an effect on the opening rates of the U.S. dollar vis-à-vis the deutsche mark ($S(DM/\$)_t$) and the yen ($S(yen/\$)_t$) in New York due to conflicting statements on the direction of U.S. policy. Humpage concludes that intervention can have an effect on exchange rate movements taking into account that "the size and duration of any announcement effect seems to depend on the extent to which the intervention creates expectations of changes in monetary and fiscal policies" [ibid., p. 15].

Eijffinger and Gruijters [1989] assume the market for foreign exchange to be highly efficient. For that reason they relate the closing rate of the U.S. dollar in deutsche mark at the Frankfurt foreign exchange market on day t (S_t^U) to the opening rate of the same day

(S_t^P), to the lagged closing rate (S_{t-1}^U), to changes in the interest differential between one-month Euro-DM and Euro-$ deposits in London during day t ($\Delta(i^{DM} - i^{\$})_t$) and to spot market intervention by the Bundesbank (I_t^{DBB}) and by the Federal Reserve (I_t^{FED}), respectively, during day t. Interventions appear to have influenced the $/DM exchange rate significantly during only one out of eight estimated periods of about six months. The estimation results for the period February 1985–June 1985 are as follows, with t-values in parentheses:

$$\begin{array}{lllll} S_t^U = -0.0063 + 0.9037\,S_t^P + 0.0988\,S_{t-1}^U - 2.0196\,\Delta(i^{DM} - i^{\$})_t \\ \quad (-0.089) \quad (8.650) \quad (0.948) \quad (-0.678) \\ +0.0196\,I_t^{DBB} - 0.0606\,I_t^{FED}; \quad \bar{R}^2 = 0.9589 \quad DW = 2.0786\,. \\ \quad (2.741) \quad (-1.188) \end{array} \tag{20}$$

From the estimated equation it can be concluded that a sale of U.S. dollars by the Bundesbank to an amount of DM 1 billion appears to have led to a depreciation of the U.S. dollar vis-à-vis the deutsche mark of approximately 2 basis points during the day on which the intervention took place. The announcement of unexpected U.S. trade balance figures proves to have outweighed the effect of interventions in other periods. Eijffinger and Gruijters do, however, find that "a selective intervention strategy and a careful timing of the interventions" [Eijffinger and Gruijters, 1989, p. 20] can improve the effectiveness. Coordinated interventions and initial interventions, defined similarly as in Humpage [1988] appear to have a larger announcement effect.

V. Conclusions

Publicly available intervention data sufficiently detailed and frequent to carry out reasonable investigations is still lacking. In spite of that, several interesting features of the objectives central banks pursued with their interventions have been uncovered. Longworth [1980] is the first study to go beyond the usual verification of leaning against the wind behaviour. The Bank of Canada is found to have reacted symmetrically across months with a rising and a declining value of the Canadian dollar in terms of the U.S. dollar. Later studies, e.g. Bischofberger [1986], Gärtner [1987] and Honegger [1989], have continued the search for asymmetries in the intervention behaviour and extended it to cover more countries. A very informative specification of an intervention reaction function leaves open the possibility that

central banks act differently in case their currency is overvalued as compared to the case in which it is undervalued with respect to purchasing power parity. Honegger [1989] finds that the Bank of Japan only leaned against the wind when the yen was overvalued. The Bundesbank appears to have been concerned with countering appreciations of the DM vis-à-vis the U.S. dollar only, while the Bank of England only opposed depreciations of sterling. The search for asymmetries in the more recent studies replaces attempts to include deviations from a target level as an explanatory variable in the reaction function in the more dated studies such as Artus [1976], Quirk [1977] and König and Gaab [1982]. Asymmetries in leaning against the wind behaviour point to specific objects central banks want to attain, e.g. low inflation and improved competitiveness of domestic industry. This contrasts with the assumption underlying most target level specifications that central banks want to bring the exchange rates in line with purchasing power parity.

In general, no systematic effect of sterilized intervention via the portfolio-balance channel is found implying that interventions do not constitute an independent tool of monetary policy. Data limitations and theoretical and econometric problems have made it impossible to estimate the portfolio balance model and measure the effects of sterilized intervention satisfactorily. Furthermore, the scale of intervention relative to the magnitude of flows in the foreign exchange market and relative to the magnitude of stocks of private foreign assets is insignificant. Therefore, on the basis of casual empiricism the potential for central banks to cause a significant imbalance in investors' portfolios seems negligible.

Only official exchange market operations which create expectations of changes in monetary policy or which embody another sufficient 'news'-content appear to have a chance of affecting the exchange rate significantly. Several attempts, such as Humpage [1988], Eijffinger and Gruijters [1989] and Dominguez [1990], have been made to detect the components of which the announcement effect is made up. In this context the extra-effectiveness of intervention carried out after a certain period of no intervention and coordinated intervention is investigated. The results are rather mixed indicating perhaps that whether or not market participants pay attention to the interventions also depends on the availability of other 'news'. Furthermore, statements of politicians and monetary authorities which accompany the intervention can lend support to or detract from its effectiveness.

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Zusammenfassung: Empirische Befunde zur Intervention auf den Devisenmärkten. Wie ist der Stand der Dinge? – Die Autoren geben einen Überblick über 15 empirische Studien, in denen die Ziele untersucht werden, die die Zentralbanken bei ihren Interventionen auf den Devisenmärkten verfolgen. Die neueren Studien gehen über die übliche Verifikation des „leaning against the wind"-Verhaltens hinaus. Es zeigt sich, daß die interventionistischen Reaktionen davon abhängen, ob sich eine Währung auf- oder abwertet und ob sie im Vergleich zur Kaufkraftparität über- oder unterbewertet ist. Außerdem werden zehn empirische Studien, die die Wirksamkeit von Interventionen untersuchen, betrachtet. Anscheinend haben nur Interventionen mit einem ausreichenden Informationsgehalt eine Chance, den Wechselkurs zu beeinflussen.

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Résumé: Des preuves empiriques sur l'intervention au marché des changes: où est-ce que nous nous trouvons? – Dans cette étude les auteurs font un aperçu de 15 études empiriques exécutées pour déterminer quels buts les banques centrales ont poursuivi avec leurs interventions au marché des changes. Les études les plus récentes ont réalisé plus que la vérification du comportement «leaning against the wind». On trouve que les réactions des banques centrales en façon d'une intervention dépendent de la direction que le cours du change va prendre (réévaluation ou déévaluation) et de la disparité entre le cours du change et la parité du pouvoir d'achat. En plus on a réexaminé 10 analyses empiriques concernant l'efficacité de l'intervention. Seulement les interventions qui contiennent beaucoup de nouvelles semblent avoir une chance d'influencer le taux de change.

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Resumen: Evidencia empírica de la intervención en el mercado de cambios: ¿dónde estamos parados? – Este trabajo pasa revista a quince estudios empíricos que han sido llevados a cabo con el fin de determinar qué objetivos persiguem los bancos centrales con sus intervenciones en el mercado de cambios. Los estudios más recientes van más allá de la usual verificación de un actividad "en contra del viento". La respuesta en forma de intervención resullta depender de si una moneda se encuentra en una revaluación o en una devaluación y de si esta sub- o sobrevaluada con respecto a la paridad del poder de compra. Además, se revisan diez investigaciones empíricas sobre la efectividad de la intervención. Sólo intervenciones que incorporan un contenido de informaciones suficiente parecen tener una oportunidad de afectar a la tasa de cambio.